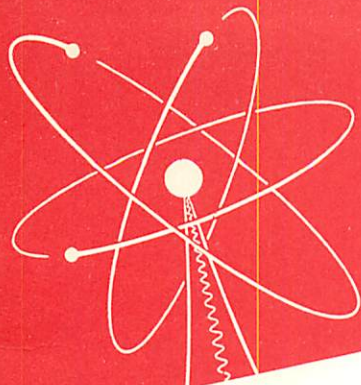




PROJECTION RECEIVERS

Lesson T2C-15A



DeVRY Technical Institute

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Formerly DeFOREST'S TRAINING, INC.

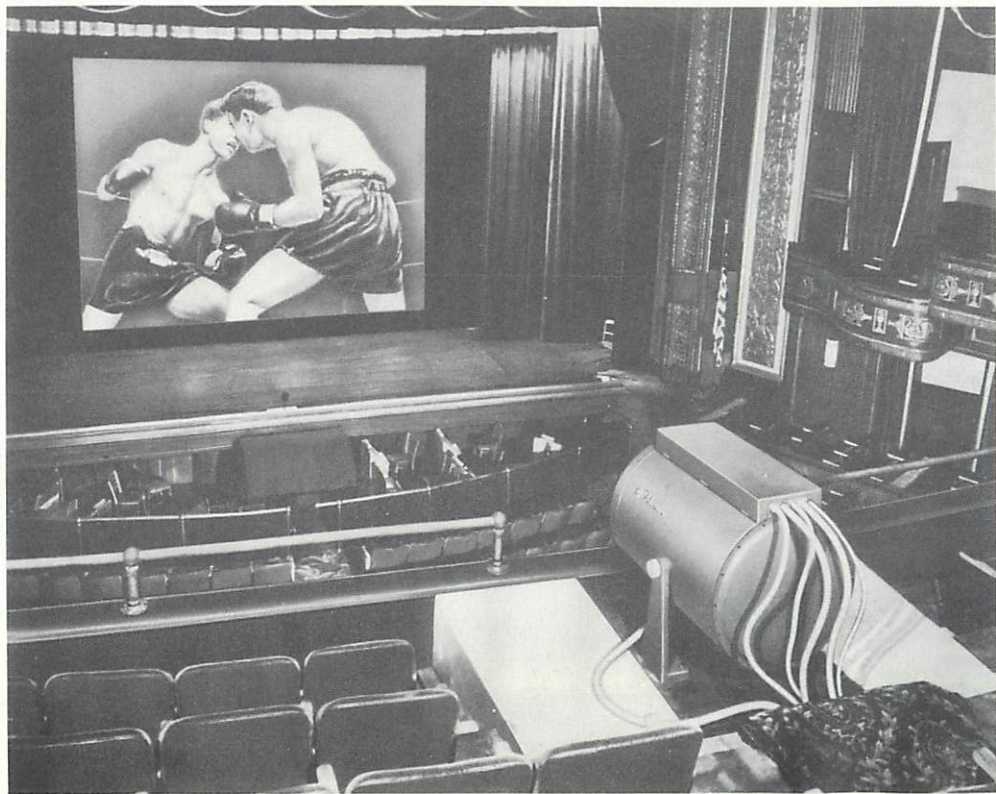
PROJECTION METHODS

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Theater television projector. Located in balcony, this unit provides a picture of large enough dimensions and brilliancy to be viewed comfortably by entire theater audience.

Courtesy RCA Victor Division of
Radio Corporation of America

PROJECTION METHODS

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The brightest flashes in the world of thought are incomplete until they have been proved to have their counterparts in the world of fact.

—John Tyndall

PROJECTION METHODS

PICTURE SIZE REQUIREMENTS

Motivated by the natural desire of the public for larger pictures than were provided by the early television receivers, the design trend has been toward increased screen size. When the television screen is viewed for long periods of time, less eye fatigue is produced if the picture does not occupy too small a field of view. On the other hand, tiring of eye muscles results if the field of view is too large, because then the eye must move constantly to scan the entire picture.

Thus, from the standpoint of eyestrain, the screen size should fall within some fairly definite range. Other factors which determine the desirable screen size are the ability of the eye to resolve the small detail in the picture, and the line structure of the raster. When the picture is too small, the eye is unable to see the smallest picture elements. The individual scanning lines are visible if the picture is too large.

Generally, the viewing distance is relatively short for the ordinary size living room and a small number of viewers. In a recreation room, business establishment, or auditorium, the larger number of viewers require a greater viewing distance. For best results, the

desirable picture height should fall somewhere between the limits of $1/5$ and $1/10$ the distance from the viewers to the screen.

For example, with a viewing distance of about 7 feet or 84 inches, the picture should be from about $84/10=8.4"$ to $84/5=16.8"$ in height. On the same basis, a viewing distance of 12 feet requires a picture height of from about 14.4" to 29", while, for a viewing distance of 50 feet, a picture height from about 5 to 10 feet is needed. Calculated on the basis of most comfortable viewing over long periods, these picture heights do not necessarily correspond with the viewing distances employed by television receiver owners.

LARGE SCREEN TELEVISION METHODS

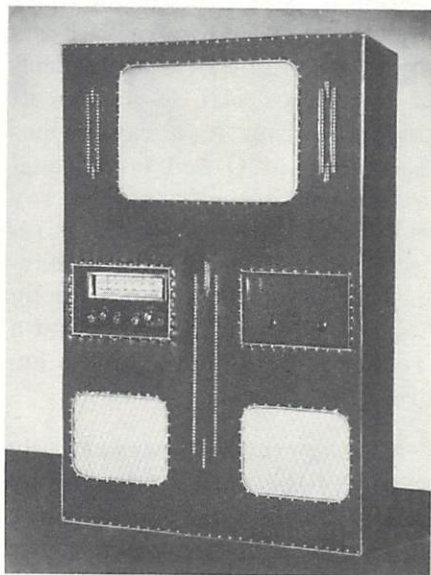
Television receivers in which the viewing screen is the coating on the inner surface of the picture tube face plate are called direct view receivers. In projection television systems, a multiple lens or a lens-mirror combination projects the image onto a screen which is outside of and some distance from the cathode ray tube. The projection screen may be located in the receiver cabinet, or it may be at the other end of a room or auditorium.

For home television reception and similar applications, different picture sizes are obtained with the direct view receivers by employing various sized picture tubes. At present, the picture tube sizes available provide picture heights up to a little less than 2 feet. According to the stated desirable relation between picture height and viewing distance, a direct view receiver with a picture height of 24 inches can be viewed most comfortably from a distance anywhere between 10 and 20 feet. For distances considerably greater than 20 feet, larger pictures should be provided, such as those obtained with a projection system.

According to the optical method employed to enlarge the image, the multiple lens type projector is called the **refractive system**, while the unit which uses a combination of lens and mirror is known as the **reflective system**. As optical systems in general, both methods have certain advantages and disadvantages which make them more or less desirable for different applications. In the case of television picture projection, the advantages of the reflective system make it the most commonly used at the present time. Both systems are described in this lesson. First, however, a few basic facts concerning lenses and mirrors are given.

MIRRORS

Any mirror has the primary purpose of reflecting light in some desired manner. The basic laws of reflection are illustrated in Figure 1 where MN represents the surface of a mirror and, from source S, light ray I strikes MN at point O. Called the "normal", dashed line D is drawn perpendicular to MN at point O, while



Designed for use in clubs or lounges, this receiver employs the refractive optical system to project a large picture onto the inside surface of the viewing screen.

Courtesy U.S. Television Mfg. Co.

ray R is the path taken by the reflected light which is traveling toward P, as indicated. In the Figure, $\angle A$ (angle A) is the "angle of incidence", while $\angle B$ is the "angle of reflection". The first

law states that THE ANGLE OF INCIDENCE IS ALWAYS EQUAL TO THE ANGLE OF REFLECTION. The second law states that THE INCIDENT AND REFLECTED RAYS I AND R, AND THE NORMAL D, ALL LIE IN THE SAME PLANE, CALLED THE "PLANE OF INCIDENCE".

Plane Mirror

On the basis of these laws, reflection by a PLANE MIRROR (flat) is illustrated in Figure 2. From object AB, light rays are reflected by mirror MN to an eye at point P. From A, a ray strikes the mirror at O and is reflected to the eye. Also, from B, a ray strikes the mirror at K and is reflected to the eye. In similar manner, rays from every point along AB are reflected by MN so that a "reflection", or image, of the entire object is seen.

Although the light rays actually travel by the paths indicated by the solid lines in the figure, so far as the eye at P is concerned, ray OP seems to be coming from point A', and ray KP from B' in back of the mirror. Also, the distance O to K is less than the length of AB. With respect to the surface of the mirror, this foreshortening of the reflection causes the image A'B' to appear to have the angle shown rather than that of AB. The fact that the complete image of AB is seen by the eye at P, even though point B is lower than

the lowest point N of the mirror, shows why a person needs a mirror only about half his own height in order to see his whole image.

A plane mirror forms an image which is turned left for right with respect to the object in front of it, as shown in Figure 3A. Optically speaking, this action is known as PERVERSION. Normally, a plane mirror does not form an inverted image, but inversion may be accomplished by positioning the object under or above the mirror, and at right angles to its surface, in which case the image is inverted but not perverted. This type of inversion is shown in Figure 3B.

If a plane mirror is positioned so the incident light rays impinge or strike upon it at an angle of 45° , according to the laws of reflection, the reflected rays will leave at an angle of 45° and the image is "turned" exactly 90° with respect to the object. This action is illustrated in Figure 4 by light rays A'B' projected on the semi-transparent screen, S. Here, ray AO is at 45° to the normal at O and BK is at 45° to the normal at K. Therefore, reflected rays OA' and KB' are at 45° to the respective normals, and the image A'B' is at 90° with respect to AB, as indicated by the lines extended to point P.

This action should be kept in mind, as it is employed in some

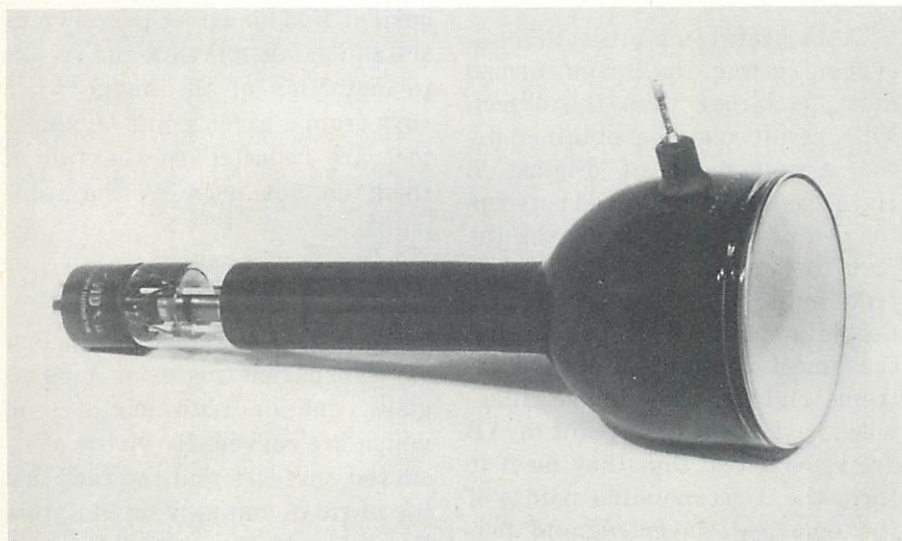
television applications of the reflective optical system.

Spherical Mirror

In Figure 5, MN represents a concave SPHERICAL MIRROR which may be thought of as a very small portion of a sphere, the center of which is at point C. Known as the

J and K, these rays are reflected according to the law of angles so that they intersect at point F called the PRINCIPAL FOCUS. Known as the FOCAL LENGTH of the mirror, the distance from F to O is equal to one-half that from C to O.

As shown in Figure 6, when object AB is placed across the axis



A projection cathode ray tube, the type TP400A has a face diameter of 4 inches, and operates with an anode voltage of 20 kilovolts. Thus, a large amount of electron beam energy is concentrated in a small area to produce an extremely brilliant picture on the tube face. This light becomes less concentrated as it is spread out by the projection system to cover the large viewing screen.

Courtesy National Union Radio Corporation

axis of the mirror, line OL passes through the center of curvature C and point O which is midway between M and N. The distance OC is the RADIUS OF CURVATURE. Light rays from an infinitely distant source are considered to be parallel to axis OL. Striking the mirror at various points such as

at the center of curvature, an inverted image A'B' is formed at the same point. This inversion is due to the fact that the various angles of incidence and reflection are such that the ray from point A to J is reflected to point A', as is the ray from A to K, and the rays from A to every other point

on MN. In like manner, all rays emanating from point B are reflected to point B'. Thus, all rays from the various points of AB above the axis are reflected to corresponding points below the axis, and vice versa, so that the image is the same size as the object, but inverted. The image is perverted also.

To be useful in a projection television system, the image formed must be larger than the object. This result may be obtained by the arrangement of Figure 7. Here, the object is located between the center of curvature C and the principal focus F. All the rays from point A of the object are reflected at points J, K, etc. so that they meet at point A' at the extreme right in the Figure. Likewise, rays from each point of AB are reflected so that they meet to form the corresponding points of the enlarged, inverted, and perverted image, A'B'. On the other hand, should the object be located further away from the mirror than point C, such as at A'B', then the image is formed at AB and is smaller than the object.

It has been assumed that the spherical mirror is a very small portion of a complete sphere, in which case the images formed are undistorted. However, if the mirror is a considerable part of a whole sphere, all rays parallel to the axis do not pass through the

principal focus as in Figure 5, but cut the axis between F and O as shown in Figure 8. With an increase of distance between the incident rays and the axis, the reflected rays cross the axis closer to the mirror, and their mutual intersections form two luminous curves known as CAUSTIC CURVES which meet in a sharp point or cusp at F. This effect is known as SPHERICAL ABERRATION and results in distortion of the image when rays from a given point on an object are reflected so that all of them do not meet at the same point.

LENSES

An optical lens consists of a disc of transparent material such as glass, one or both surfaces of which are curved. By virtue of its curved surfaces and the fact that its OPTICAL DENSITY is different from that of the surrounding medium (usually air), a lens has the ability to change the direction of the light passing through it. This bending of the rays of light is known as REFRACTION.

According to the way in which they bend light rays, lenses are classified as CONVERGING or DIVERGING. A converging lens causes the light rays to bend toward the axis of the lens, while a diverging lens causes the rays to spread out or bend away from the axis.

Shown in Figure 9 are cross-sections of three types of converging lenses. That of Figure 9A is known as DOUBLE CONVEX, that of Figure 9B as PLANO-CONVEX and that of Figure 9C as MENISCUS. Notice that each is thicker at the center than at the edges.

Figure 10 shows how an image is formed by a double convex lens. Here, after passing through the lens, light rays from object AB form the image, A'B'. Inside the lens, point O is called the OPTICAL CENTER, and is defined as the point of mutual intersection of all rays that are not deviated or bent by the lens. Examples are rays b and e. All rays, such as a and f, which arrive parallel to the axis X-Y, intersect at the FOCAL POINT F. The distance between points F and O is the focal length of the lens.

When the distance from object AB to O is greater than but less than twice the focal length, the light rays are bent to form an inverted and perverted image which is larger than the object. For example, all rays emanating from point A, such as rays a and c, are bent so that they intersect undeviated ray b at point A'. The various rays emanating from point B are bent in such a manner as to intersect undeviated ray e at point B'. Rays emanating from all other points on AB pass through the lens and intersect at correspond-

ing points on A'B'. The ratio of the size of A'B' to that of AB is called the MAGNIFICATION of the lens and depends upon the amount the light rays are bent passing through the lens.

Figures 11A, B and C show the cross-sections of three types of diverging lenses known as DOUBLE CONCAVE, PLANO-CONCAVE and CONVEXO-CONCAVE, respectively, each of which is thinner at the center than at the edges. Figure 12 illustrates the image forming action of the double concave lens. From object AB, rays a, b, c and d pass through the lens as shown.

Because of its direction upon emerging from the lens, when it reaches the eye of an observer, ray a appears to be coming from point A'. Thus, point A' is the apparent source of the emerging ray a, and is the point of intersection of the undeviated ray b and the backward projection of a, indicated by the dashed line. Similarly, A' is the point of intersection of ray b and the backward projections of all deviated rays which actually originate at point A on the object. Likewise, point B' is the point of intersection of the undeviated ray c and the backward projections of all deviated rays originating at point B. As every point on AB has a corresponding point on A'B', an image of AB appears to be formed at A'B', between the focal

point F and the optical center O of the lens.

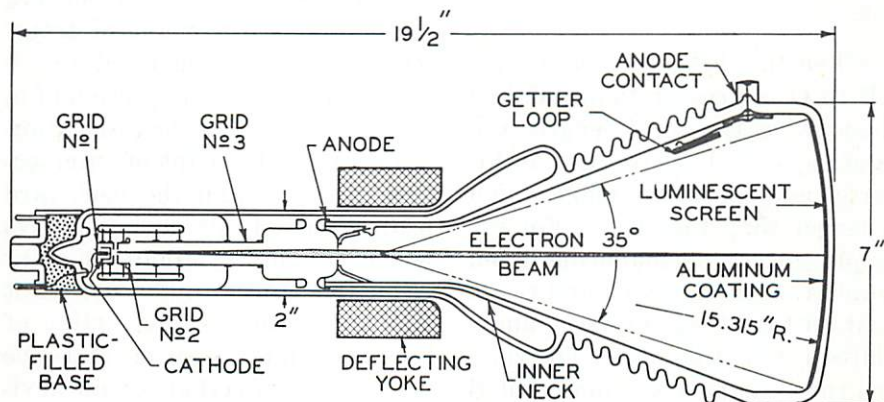
A'B' is smaller than the object, is neither inverted nor perverted, and is called a VIRTUAL IMAGE because it is located on the same side of the lens as the object. Point F is virtual also, as it is the point of intersection of the backward projections of the refracted rays a and d which were parallel to the axis upon arrival at the lens. Actually, no rays intersect at either A', B' or F, but only appear to do so to an observer located on the other side of the lens.

Besides spherical aberration like that explained above for mirrors, various types of lenses have other inherent defects, all of which tend to distort the image.

When two or more different lenses are combined, each will tend to neutralize the aberrations of the others and some arrangement of this kind is normally employed in the lens assemblies of projection equipment. A combination consisting of a concave lens and a convex lens is known as a COMPOUND LENS, while that consisting of a concave or convex lens with a convexo-concave or a meniscus is called a DUPLEX LENS. A typical lens assembly, made up of a duplex lens and a compound lens, is shown in Figure 13.

REFLECTIVE OPTICAL SYSTEM

The optical principles employed in television projection systems have been used in other fields for many years. Suggested first by



Cross-sectional drawing showing construction of the type 7NP4 projection crt used for theater television. The 80 kilovolt anode voltage requires special design such as the circumferential corrugations in the cone to increase the surface leakage path length, and the vacuum insulated double neck arrangement to prevent breakdown through the glass wall of the tube.

Courtesy Radio Corporation of America

Gregory about 1663, the arrangement of Figure 7 was employed several years later by Newton to construct the original reflecting telescope. In this application, A'B' is the object, and is at a great distance. Therefore, the image AB has a much smaller relative size, thus approaching the conditions of Figure 5. This small image is magnified by a lens similar to that of Figure 13.

About 1906, an American lens designer named Kellner, patented an optical system for searchlights and automobile headlights. Including a spherical mirror and a correcting lens, this system is essentially the same as that employed in projection television receivers. Then at the Hamburg Germany Observatory in 1931, an instrument maker by the name of Schmidt developed this same system for taking astro-photographs. Schmidt's equipment was used extensively by astronomers and became quite well known. Thus, the television application of the reflective optical system is commonly called, SCHMIDT OPTICS or the SCHMIDT OPTICAL SYSTEM.

Referring to the simplified sketch of Figure 14, in the Schmidt astro-photographic device, the incoming light rays pass through the correcting lens and are then reflected from the spherical mirror to the photographic plate where they form an image of the

object to be studied. As a relatively large amount of light is concentrated into a small area, the system has comparatively high efficiency. The correcting lens introduces spherical aberration equal but opposite to that introduced by the mirror so that one neutralizes the other.

In the television reflective optical system, the object and image locations are reversed with respect to the Schmidt system. The picture tube face is the object. As shown in Figure 15, emanating from the tube face, light rays are reflected by the spherical mirror and pass through the correcting lens to form an enlarged image on the screen. Besides the relatively high light transfer efficiency of this arrangement, a spherical mirror has only about one-eighth the amount of spherical aberration of a single lens of like focal length and diameter.

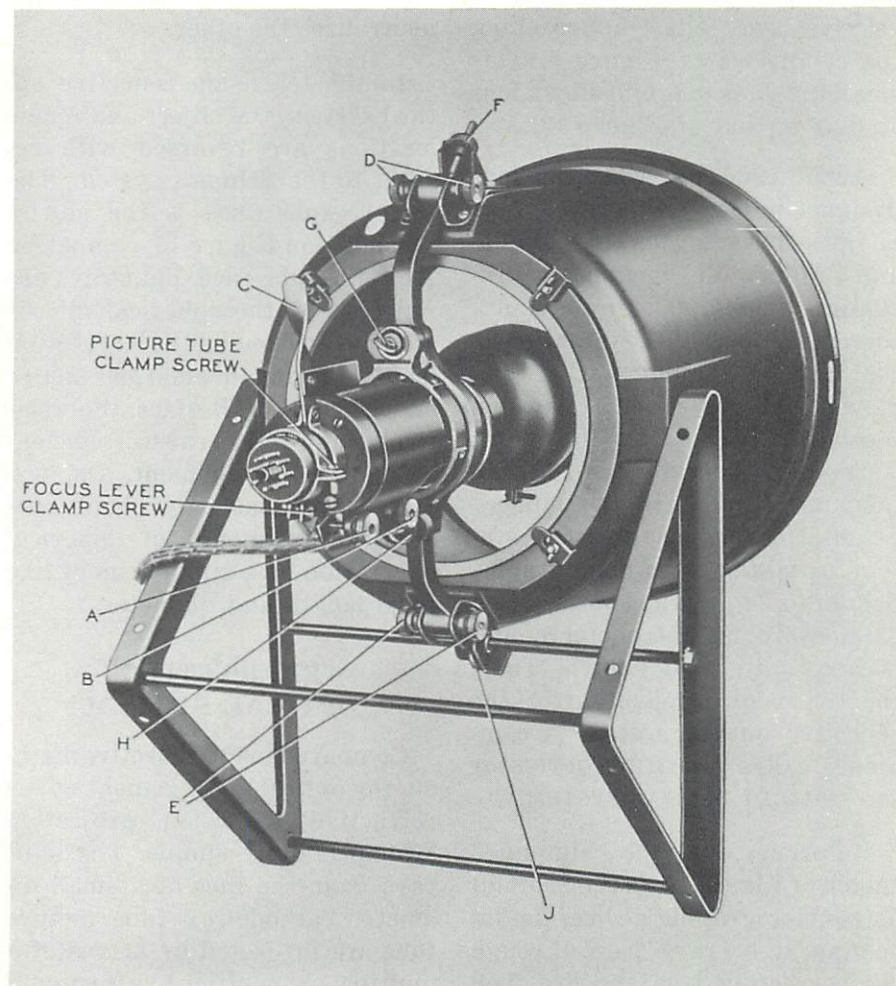
REFRACTIVE OPTICAL SYSTEM

Compared to the reflective method, the optical arrangement of the refractive television projection system is quite simple. The light rays from the face of a small diameter cathode-ray tube picture tube are projected by means of a multiple-element lens system onto the viewing screen of the desired size. When the screen is entirely separate from the television re-

ceiver cabinet, a fairly wide choice of image or screen sizes may be accommodated by merely making an adjustment of the lens, as with the usual film projector.

The greatest limitation of the refractive system is its relatively

low light-transmission efficiency. In a multi-element lens, considerable light is lost by the undesirable reflections from each of the various air-to-glass surfaces. Some reduction of this loss can be achieved by the use of an anti-



The optical barrel assembly of a reflective projection system designed for use in home television receivers.

Courtesy Philco Corp.

reflection coating on the lens surfaces which tends to reduce the internal reflections of the lens assembly. In general, the light-transmission efficiency of a system of this type is on the order of from 5 to 15 per cent.

COMMERCIAL LARGE SCREEN TV EQUIPMENT

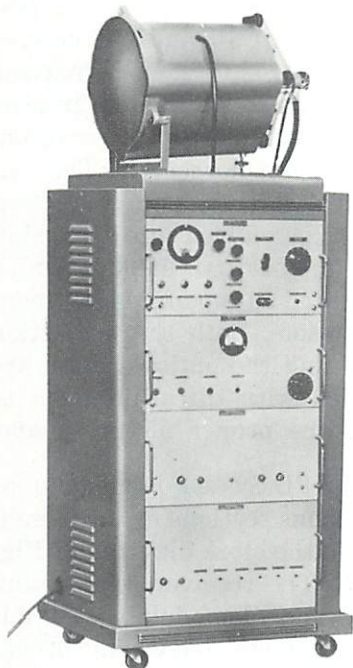
There are many situations in which it is desirable to provide a television picture which is large enough to be seen by a considerable number of people. With a large screen system, television broadcasts can be watched by groups in schools, clubs, hotels, hospitals, and so on. In addition to "on-the-air" programs, this type of equipment is used with **closed circuit** or "wired" television systems. Picked up by studio or industrial cameras, the visual information is transmitted by telephone lines to the point or points at which it is to be viewed by groups of people. These groups may consist of surgical, dental, or other students, factory personnel learning to operate complex machines, or sales and service people in cities far from that in which the parent organization is located. Frequently, convention audiences are too large to get into any single hall or auditorium. In these cases the overflow audience can watch the proceedings by means of projection television

screens located in other rooms or halls.

For applications of this kind, projection television equipment is manufactured by a number of companies. An example is the Television Projection System Model PB-610 made by General Precision Laboratory, Inc. This unit employs the reflective optical system of Figure 15, and the receiver is designed to provide bright, clear pictures up to 9 x 12 feet in size. This picture usually is projected onto a portable screen. The crt, spherical mirror, and correcting lens are assembled into a housing called the **OPTICAL BARREL**, which is mounted on top of a mobile control console. Both the projection screen and the optical barrel are provided with tilt adjustment to obtain the proper picture shape.

The GPL System is made up of the various sections or units indicated in the block diagram of Figure 16. The receiver section amplifies and demodulates signals received from television broadcast stations. Its video and audio outputs are applied to a switch circuit in the control panel. For closed circuit operation, two sources can transmit video and audio signals by telephone lines 1 and 2 to inputs provided in the control panel. From whichever input is being employed, the control panel provides one video output to synchronize the sweep cir-

cuits, another to the video amplifier, and an audio output which can be applied to any suitable PA system. The sweep circuits, video amplifier, and high voltage supply apply their respective voltages to the projection type crt which, as mentioned, is located in the optical barrel.



The control console and optical barrel of a reflective projection system described in this lesson.

Courtesy General Precision Laboratory, Inc.

The physical appearance of the unit is shown in the drawing of Figure 17. Mounted on wheels, the control console contains the control panel, the television receiver, the low voltage supply,

and the sync-sweep chassis. Also wheel mounted, a separate cabinet houses the high voltage supply. The control panel contains a program selector switch, audio gain control, contrast, focus, and hold controls. A panel mounted meter indicates the crt beam current.

Pilot lamps indicate when power is applied to the console circuits, when high voltage is applied to the crt, and when high voltage has been automatically removed due to sweep failure. The receiver and sync-sweep chassis panels contain the tuning, gain, and raster controls. A meter indicates when correct tuning of the r-f oscillator is obtained.

On the panel of the high voltage supply cabinet, a meter indicates the high voltage output level in kilovolts, and a control permits setting the high voltage level. In the drawing, the end of the crt neck can be seen protruding from the forward end of the cylindrical optical barrel mounted on top of the console.

Figure 18 shows a block diagram of the dual-channel type television receiver section. The r-f section provides a picture i-f output of 25.75 mc and a sound i-f output of 21.25 mc. A four-stage picture i-f amplifier increases the level of the picture signal. This signal is demodulated by a crystal diode detector, and the video signal is amplified in a

two-stage v-f amplifier before its application to the control panel. The sound signal passes through a three-stage i-f amplifier, is demodulated by a discriminator, and the resulting audio signal increased in level by a two-stage a-f amplifier. The actual r-f, i-f, v-f, and a-f circuits are the same as those described in previous lessons on home type television receivers. This similarity to home type receivers is true also of the sync and sweep circuits and the low voltage supply.

In simplified form, the circuits of the control panel, video ampli-

fier, cathode ray tube, and high voltage supply are given in Figure 19. At the upper left, the control panel circuits contain switches S_1 , S_2 , S_3 , and S_4 , resistors R_1 , R_2 , and R_3 , contrast control R_7 , and the a-f output "T" or attenuator pad, $R_4R_5R_6$. The video amplifier contains the four tubes, V_1 , V_2 , V_3 , and V_4 . Diode V_3 operates as a d-c restorer, and to maintain the reinserted d-c level, the third amplifier tube V_4 is directly coupled through peaking coil L_3 to the cathode of projection crt V_8 .

The d-c restorer action supplies a direct voltage which opposes the

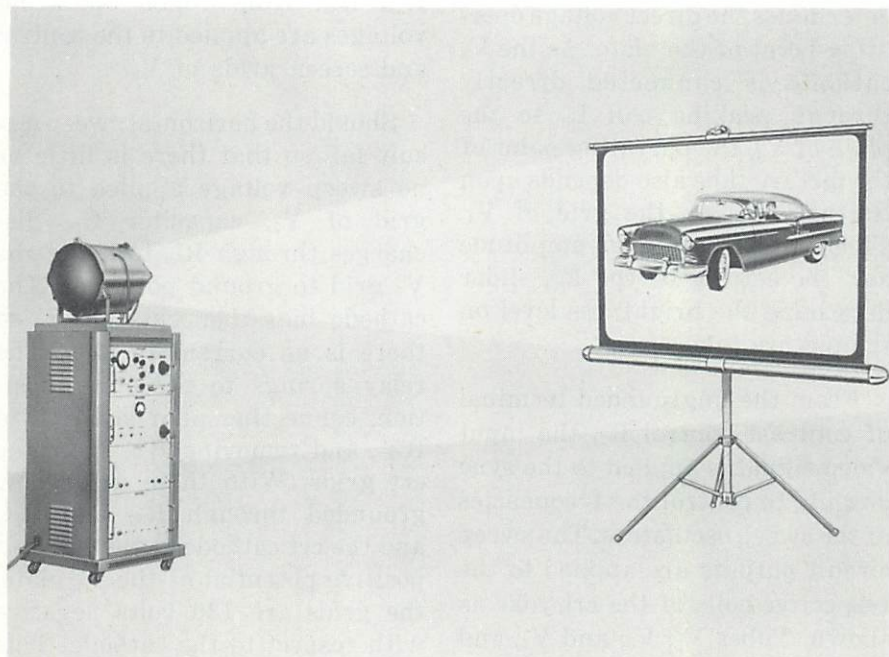


Photo illustrates the operation of the GPL television projection system.

Courtesy General Precision Laboratory, Inc.

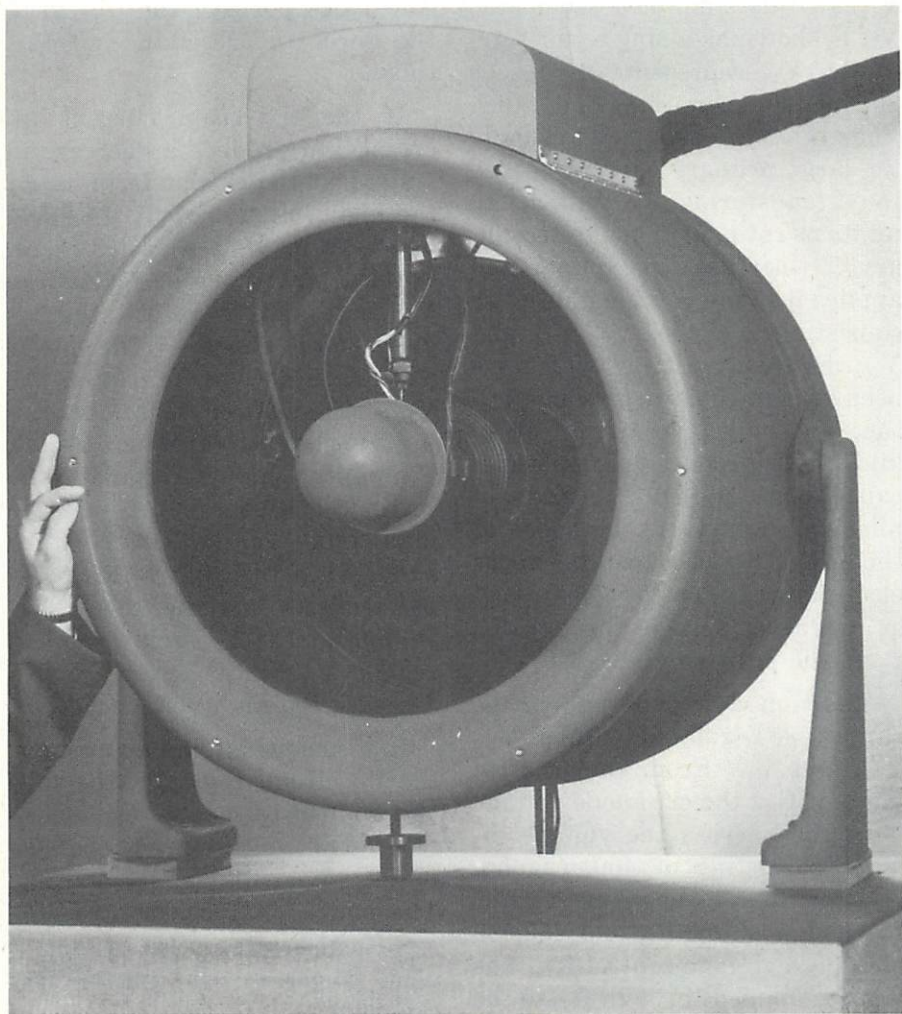
negative bias on the V_4 grid. From the plate of V_2 , the video signal with negative going sync pulses discharges C_6 with electron flow through R_{20} and V_3 into C_7 . Between sync pulses, C_6 recharges with electron flow from C_7 through R_{21} and R_{20} , thus making the upper end of R_{21} positive with respect to the slider on brightness control R_{24} . For example, if the signal develops 17 volts across R_{21} , and the brightness control is adjusted so the slider on R_{24} is at -23 volts with respect to ground, then there is a net bias of 17-23, or -6 volts applied to the grid of V_4 . The V_4 grid operating point determines the direct voltage operating point of the plate. As the V_8 cathode is connected directly through peaking coil L_3 to the plate of V_4 , the operating point of the picture tube also depends upon the net bias on the grid of V_4 . Thus, both the signal amplitude and the setting of the R_{24} slider determine the brightness level on the picture tube screen.

From the ungrounded terminal of contrast control R_7 , the input video signal is applied to the sync circuits to control the frequencies of the sweep oscillators. The sweep circuit outputs are applied to the respective coils of the crt yoke as shown. Tubes V_5 , V_6 , and V_7 , and relay CR_1 form a protective circuit which removes the operating voltages from the control and

screen grids of the crt in the event the horizontal sweep circuit fails.

The horizontal sweep output voltage is applied through C_9 to the grid of V_5 , and the amplified output of this tube is applied to diode V_6 . Diode current charges C_{11} to the indicated polarity. Applied to the grid of V_7 , this positive voltage $E_{C_{11}}$ counteracts the positive bias on the cathode to cause plate current. Carried by the CR_1 winding, V_7 plate current produces a flux which attracts the movable contact to the right as shown. This action connects B+ voltage to the voltage divider, R_{36} , R_{37} , R_{38} , from which operating voltages are applied to the control and screen grids of V_8 .

Should the horizontal sweep circuit fail so that there is little or no sweep voltage applied to the grid of V_5 , capacitor C_{11} discharges through R_{33} to bring the V_7 grid to ground potential. The cathode bias then cuts off V_7 so there is no current in CR_1 . The relay springs to the other position, connecting pilot lamp P_1 to B+, and removing B+ from the crt grids. With these grids now grounded through R_{37} and R_{38} , and the crt cathode at the 130 volt positive potential of the V_4 plate, the grids are 130 volts negative with respect to the cathode. This bias cuts off the beam in the crt. With B+ applied, P_1 conducts current and therefore glows. This



View showing the cathode ray tube and the spherical mirror inside the optical barrel of a reflective projection system.

General Precision Laboratory, Inc.

pilot light is mounted on the control panel, and, when lighted, indicates that the crt beam has been cut off due to sweep failure.

The high voltage supply circuits are shown in the lower por-

tion of Figure 19. The V_9 circuit at the left is a Colpitts type sine wave oscillator, the output of which is amplified by the buffer stage, V_{10} , and then applied to the grid of the output amplifier tube

V_{11} . In this simplified schematic, V_{11} is shown as a single tube. Actually, V_{11} represents four type 807 pentodes connected in parallel. Four tubes are required to supply the large primary current needed in r-f transformer T_1 . With a step up turns ratio, primary to secondary, T_1 increases the voltage and applies it to the voltage multiplier consisting of diodes V_{14} , V_{15} , and V_{16} , the basic action of which has been explained in a previous lesson. The multiplier output of 40 kilovolts is produced across series capacitors C_{30} and C_{31} , and applied through R_{39} to the anode of the crt. The electrostatic focus electrode of the crt receives a lower operating voltage through R_{61} from the positive plate of C_{27} .

The high voltage outputs of the supply are regulated by tubes V_{12} , V_{13} , and V_{17} . From the positive plate of C_{30} , the crt anode voltage is applied across the voltage divider consisting of 400 megohm resistor R_{62} , 1 megohm resistor R_{57} , meter shunt R_s , and 450,000 ohm high voltage control R_{58} . The voltage applied through R_{55} to the grid of V_{13} is less positive than that applied from the upper end of R_{58} to the cathode. The slider on R_{58} sets the operating point of V_{13} . The plate current of V_{13} determines its plate voltage, and this voltage is applied through R_{52} to the grid of V_{12} . Pentode V_{12} acts as a variable resistance in the screen supply circuit of V_{11} .

The more positive the V_{12} grid, the lower the resistance of this tube.

If the crt beam current increases, to produce a decrease in voltage at the output terminal of the high voltage supply, the grid of V_{13} is made less positive. Decreased plate current makes the V_{13} plate and, therefore, the V_{12} grid more positive. The lower plate resistance of V_{12} causes the V_{11} screen voltage to rise, increasing V_{11} plate current. As a result, T_1 applies a higher voltage to the rectifier circuits, to increase the high voltage output. On the other hand, when the high voltage output tends to increase, the higher voltage at the V_{13} grid produces regulator circuit actions which decrease the high voltage output.

In a somewhat similar manner, the V_{17} circuit regulates the voltage applied to the crt focus electrode. This voltage is applied also to the voltage divider R_{63} and R_{64} . The slider on focus control R_{64} sets the operating point of the V_{17} grid. Negative grid bias is obtained by connecting the V_{17} cathode to the junction between the B+ divider resistors R_{56} and R_{58} . As the upper end of R_{63} connects to the plate of V_{17} , the plate voltage of this tube is also the crt focus electrode voltage. Any decrease in this voltage makes the V_{17} grid less positive to reduce plate current. Carried by R_{61} , the

plate current decreases the voltage across this resistor. As a result, the V_{17} plate voltage and therefore the crt focus electrode voltage rises. Conversely, if the focus voltage tends to increase, the higher V_{17} grid voltage increases plate current, resulting in a decrease in voltage at the plate, and at the focus electrode of V_8 .

THEATER TELEVISION

Another important application of the projection system is in theater television. On-the-spot pick up equipment sends the video information by wire or uhf radio waves to a central station. From here it is distributed by closed circuit to one or more theaters. In this way, important news events, feature sport attractions, and dramatical or musical presentations are shown to large audiences located at a distance from the point of occurrence.

In any given projection system, to increase the size of the projected picture, the throw distance between the projector and screen is increased. Since the light spreads out as it approaches the screen, the amount of light per unit area is very much less at the screen than at the projector. Therefore, the maximum screen size that can be used, and still give a bright enough picture, is limited by the light output of the projector. In the GPL system described above,

picture brightness is adequate when the projector and screen are separated by a distance of up to about 19 feet. This throw provides a picture 9 feet high by 12 feet wide. An even larger picture is needed for theater screens, thus requiring a greater throw, and greater light output from the projector.

Projection Unit

A typical theater television projection system employs the reflective system with the picture tube, spherical mirror, and correcting lens contained in a housing constructed on the general plan of Figure 20. The projection tube has a diameter of 15 inches and operates with an anode voltage of 80,000 volts. The spherical mirror has a diameter of 42 inches, and the aspherical correcting lens a diameter of 36 inches. The throw of this unit is 40 feet which permits its installation in the balconies of the theaters. Picture signals can be fed to this projector from any regular television source such as network coaxial cables, microwave relay source, studio or camera pickup sources, etc.

Theater Equipment

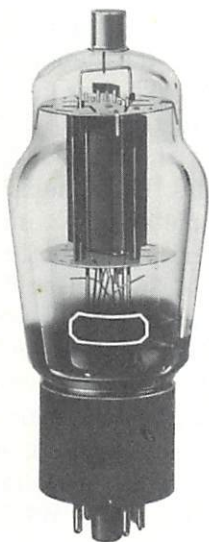
Figure 21 shows the general arrangement of equipment at the receiving end of the theater television system. The video and audio

signals arrive by telephone line and are applied to the v-f and a-f amplifiers. The a-f amplifier drives the loudspeaker system, while the video signal is coupled to the sync circuits and the control electrode of the crt. Also supplied to the crt are the outputs of the high voltage supply and the sweep circuits. As in the high voltage supply of Figure 19, the system of Figure 21 employs a high-frequency sine wave oscillator as the source of alternating voltage. This method limits the high voltage

ness, focus, and framing of the picture.

Skiatron System

A method of projecting television images on a theater screen by "light valve" control of the light from a source of constant brightness is illustrated in Figure 22. Known as a Scopphony Skiatron, the crt contains a crystal screen which has the property of changing its ability to pass light when struck by the electrons of the scanning beam. As the beam moves over this screen, it causes each elementary area to become opaque to a degree which depends upon the instantaneous intensity of the beam. This "opaqueness" travels through the crystal screen to the anode, where it disappears.



Like direct view TV receivers, projection type receivers use heavy duty horizontal output tubes similar to the one shown.

shock hazard for the operating personnel. Various operating controls mounted on the unit permit the operator to adjust the bright-

With the proper combination of screen thickness and anode voltage, the opaque areas require the frame period of $1/30$ of a second to move through the screen. Thus, at the instant the opaque deposit in a given elementary area reaches the anode and disappears, the beam has completed a frame cycle and arrives at this area to create a new opaqueness corresponding to the requirement of the next frame. In turn, this new deposit moves through the screen to the anode which it reaches at the end of the frame period. This process achieves "storage" action, since each elementary area remains at

a given opaque level during the entire $1/30$ of a second while an opaque deposit is moving through it. The same action takes place for every tiny area on the screen, thus the crystal screen contains an "opaqueness" image of the televised scene.

Referring to Figure 22, light from the source is reflected so that a concentrated beam passes through the condenser lens to the anode side of the crystal screen. The anode is transparent, and the light passes through it and the screen to the projection lens which projects the light onto the viewing screen. Modulated in intensity by the video signal, the electron beam causes each elementary area on the crystal screen to have an instantaneous opaqueness which depends upon the brightness of the corresponding area in the televised scene.

Therefore, the light which comes through the crystal screen at any point is determined by the instantaneous amplitude of the video signal at the instant the scanning beam touched that point to create the opaque condition. In this way, each elementary area in the Skiatron tube screen acts like a light valve so that the rectangle of light transmitted by the crystal screen forms the desired image on the viewing screen. An advantage of this method, is that the constant-light source can be a type

which supplies much more illumination than the screen of a cathode ray tube, to provide a bright picture on the viewing screen.

HOME PROJECTION RECEIVERS

Reflective System

One arrangement used in home type projection television receivers is shown in Figure 23. Here, the spherical mirror is mounted at the bottom of the cabinet with its axis vertical, the reflected rays being projected straight up through the correcting lens to a plane mirror mounted at an angle of 45° . The mirror bends the rays 90° so that the image is focused upon the translucent viewing screen mounted in the front of the cabinet.

The various distances are adjusted until the translucent screen is at the correct total optical distance, or throw, from the spherical mirror so that the screen is at the exact point where the image is formed by the converging rays. For example, letting the picture AB on the picture tube face represent the object, the paths of two rays from point A are shown to be reflected from the spherical mirror so that they converge and strike the plane mirror at two points quite close together. Leaving the 45° plane mirror, the two rays continue to converge and finally meet at point A' on the

viewing screen. Two similar paths of light, point B on the picture tube face, meet at point B' on the screen.

White light is a combination of all the colors of the rainbow, and passing through the correcting lens, the various colors will come to a focus at different points, tending to produce an image having colored fringes. Called CHROMATIC ABERRATION, this effect is especially noticeable when the rays enter the lens at a considerable angle, and is prevented in the system of Figure 23 by virtue of the fact that the center of the spherical mirror is non-reflective. Often this central area is omitted, and the mirror configuration is much like that of a saucer with the cup resting surface removed.

With an arrangement of this type, a flat object normally is reflected as a curved image. This action is due to what is called, CURVATURE OF FIELD and, since the viewing screen is flat, a curved object must be employed to obtain the flat image necessary for good focus over the entire screen. To provide an object having the correct amount of curvature, the projection television receiver picture tube has a face with a radius of curvature equal to a little less than one-half that of the spherical mirror. With this arrangement the portions of the two spheres facing each other are approximately concentric.

Although used to prevent spherical aberration, the correcting or aspherical lens should not disturb the optical system in any other way. Therefore this lens diverts the light rays only slightly, and is located at the center of curvature of the mirror. Preparing and polishing a glass correcting lens of the special shape required is difficult, costly and time consuming. However, this problem has been overcome by processing the lens from heated plastic formed in precision molds while under high pressure. With this method, the production line manufacture of these lenses is so precise that no polishing, surfacing or finishing is necessary before insertion in the optical system. The optical properties of plastic are superior to those of glass and, in addition, it provides higher transmission as well as less scattering of light rays.

Ordinary mirrors have the reflective surface on the back of the glass and the small amount of light reflected by the front surface of such a mirror produces a "ghost" when the incidence and reflected rays are at an angle to the normal, as in Figure 23. To prevent this, the 45° plane mirror is designed to reflect from its front surface only, and therefore is known as a FRONT-SURFACED mirror.

In some receivers, the translucent viewing screen is composed

of two sheets of Lucite-plastic having a layer of diffusing material between them. The front sheet has a large number of fine vertical ribs molded into its outer surface so as to increase the horizontal viewing angle above that obtained with a flat surface. The back sheet is molded into the shape of what is known as a FRESNEL LENS. This is a thin lens which is shaped so as to have the optical properties of a much thicker lens, and its purpose is to concentrate the light into a relatively narrow vertical angle. This viewing screen assembly gives a light-output of approximately five times that obtained with a ground glass screen.

Due to absorption by the various mirrors and lenses, only about one-fourth of the light emitted from the picture tube face reaches the viewing screen. To obtain a high degree of brightness, a 3 x 4 inch raster is produced on the aluminized screen of a 5-inch picture tube operating with an anode voltage of about 27,000 volts. A representative viewing screen size is 15 x 20 inches, in which case the picture area is increased from 12 square inches on the tube face to 300 square inches on the screen, or by $300/12=25$ times. Thus, the light which does reach the screen is spread out over 25 times the original area, so that the light intensity on the picture tube face must be about $4 \times 25=100$ times that desired on the viewing screen.

As shown in the cross sectional drawing of Figure 24, a somewhat different arrangement of the optical components is employed in a compact projection package developed for use in home receivers. This equipment consists of a cathode-ray tube mounted in a projection box.



In this home type television receiver, a refractive optical system projects the picture onto a 45° plane mirror which reflects it to the viewing screen. The light passes through the screen to make the image visible to the viewers.

Courtesy U.S. Television Mfg. Corp.

Known as the "Folded Schmidt System", it differs mainly from other systems in that the projection box, or optical unit, is arranged so that the light rays, reflected from the spherical mirror,

are bent or folded before passing through the correcting lens. This folding is accomplished by means of the 45° plane mirror with an elliptical center hole to accommodate the picture tube. Because of this arrangement, the rays leave the optical unit at an angle of 90° to the axis of the picture tube. A second difference is that the optical unit has very small dimensions, a feature which provides large screen television with comparatively small cabinets.

The projection cathode-ray tube is a type 3NP4, on the 2.5 inch diameter face of which a raster 1.4×1.86 inches is formed. This small raster requires a total deflection angle of only 40° and a deflection current amplitude about the same as that used for a 10-inch cathode-ray tube. The deflection coils are mounted inside the optical unit, while the focus coil is mounted outside.

The face plate of the tube is of special glass which, unlike ordinary glass, does not become discolored by the X-rays produced by the high-intensity electron bombardment. The light output is increased by means of an aluminum coating on the inner surface of the fine grain phosphor screen.

The anode terminal is surrounded by a glass cup which prevents corona discharges into the air. The grounded outside aquadag coating serves as a static shield,

while capacitance between this coating and the anode inside coating serves as the output filter capacitance for the high voltage power supply.

One method by which the optical unit may be employed to accommodate a table model type cabinet is shown in Figure 25. Here, two external plane mirrors are required to complete the optical system. The light rays from the picture tube are reflected by spherical mirror M_1 , again by plane mirror M_2 and projected through the aspherical corrector lens L to fall on the plane mirror M_3 . From here the rays are reflected to plane mirror M_4 which directs them to screen S where they form an image. With a larger cabinet, less "folding" of the image is necessary.

Refractive System

Whereas, the mirror, lens, tube and screen in a reflective system must all be precision-aligned in three dimensions, these positioning operations are largely avoided in the less elaborate optical mounting method employed by the refractive system. The cost of a lens is proportional to its diameter, and both cost and diameter may be substantially reduced by using a small diameter cathode ray tube. Furthermore, metalized picture tube screens and precision electron beam focusing permit

higher voltage on the second anode. This, in turn, provides brighter images to make up, to some extent, for the low optical efficiency of the refractive system.

Figure 26 shows the optical path employed in a refractive projection television receiver. The projection picture tube has 5-inch diameter screen and is operated with 27,000 volts on its anode. The lens is a five-element coated unit of precision design having an effective diameter of 2.63 inches. The projected light beam is bent at a 90° angle by means of the 45° front surface plane mirror and the image is formed on the viewing screen mounted in the front of the receiver cabinet. Screen sizes employed by this manufacturer are 15 x 20 inches and $22\frac{1}{2}$ x 30 inches. Designed on the same plan, a projection receiver produced by another maker uses a 20 x 26 inch viewing screen.

Refractive optical systems have been used for even larger projection installations. One such unit projects a 7 x 9 foot image on an external screen. Other units permit viewing on screens ranging

in size from 6 x 8 feet to $7\frac{1}{2}$ x 10 feet. For the latter screen size, the lens has an effective diameter of approximately 4.8 inches, and a specially designed picture tube has been designed to operate at an anode potential of 100,000 volts. The throw to the screen is about thirty feet.

This lesson has presented the basic principles involved in projection television systems. As in other fields of endeavor, modifications of these methods will be developed, and more than likely the elaborate systems will decrease in use in view of manufacturing costs. However, for most projection television applications these explanations form the basis for understanding the principles of operation.

The next lesson describes the only section of the television receiver not yet taken up, the low voltage supply. Although similar to the voltage supplies employed in radio receivers, the television low voltage supply has certain requirements and circuit arrangements which are not encountered in other electron equipment studied so far.



IMPORTANT DEFINITIONS

CLOSED CIRCUIT—A system in which the signals are transmitted by wire from the sending point to a particular desired group of receiving points. The system is “closed” to all other receivers.

LIGHT TRANSMISSION EFFICIENCY—The ability of a material to permit light to pass through it.

REFLECTIVE OPTICAL SYSTEM—In television, the projection system in which a curved mirror forms the means of enlarging the image.

REFRACTIVE OPTICAL SYSTEM—In television, the projection system in which a lens provides the enlargement of the image.

THROW—In projection systems, the distance from the center of the viewing screen to the lens of the projector. In the reflective system, the throw is measured from the screen to the corrector lens.

STUDENT NOTES

STUDENT NOTES

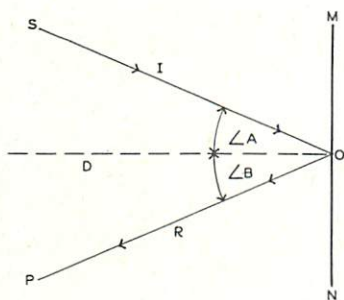


FIGURE 1

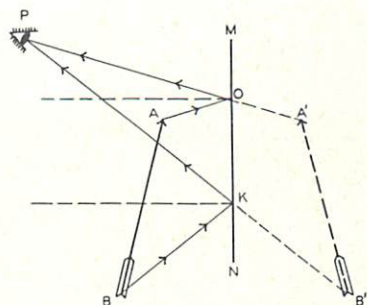
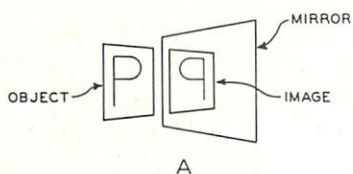
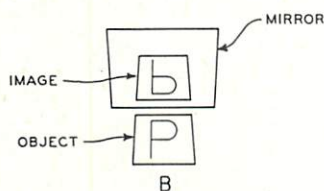


FIGURE 2



A



B

FIGURE 3

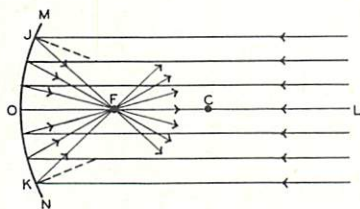


FIGURE 5

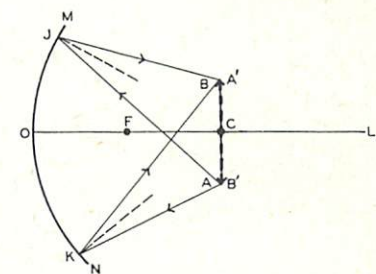


FIGURE 6

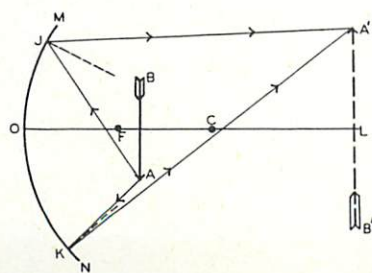


FIGURE 7

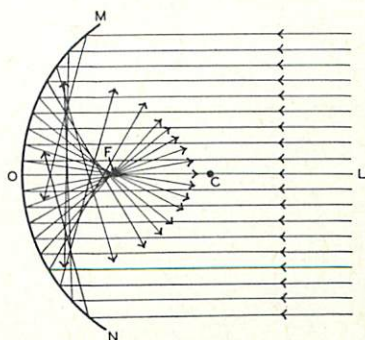


FIGURE 8

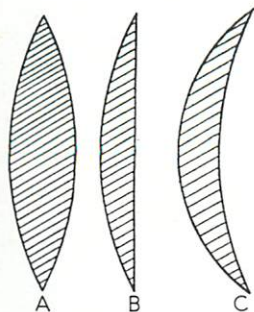


FIGURE 9

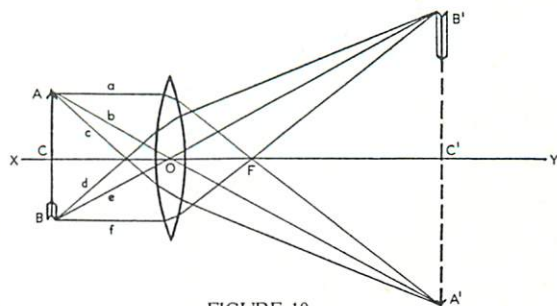


FIGURE 10

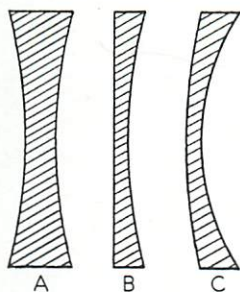


FIGURE 11

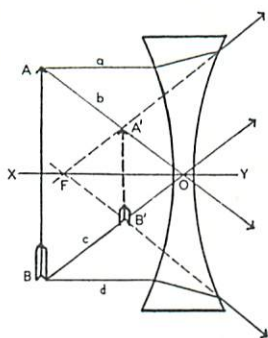


FIGURE 12

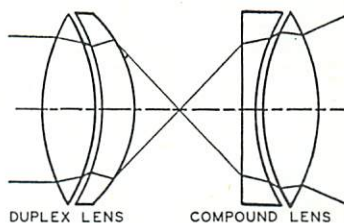


FIGURE 13

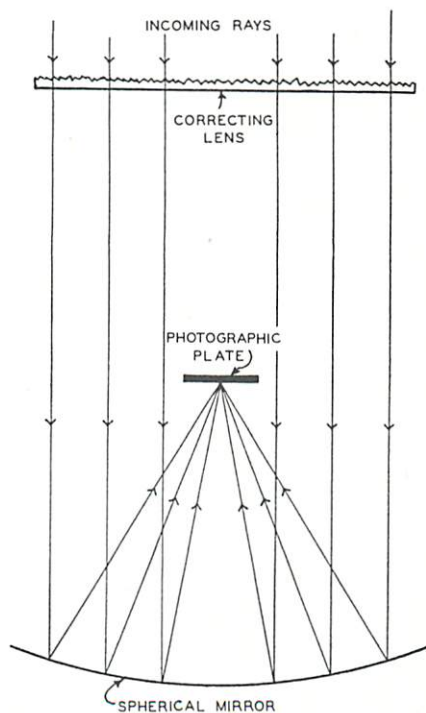


FIGURE 14

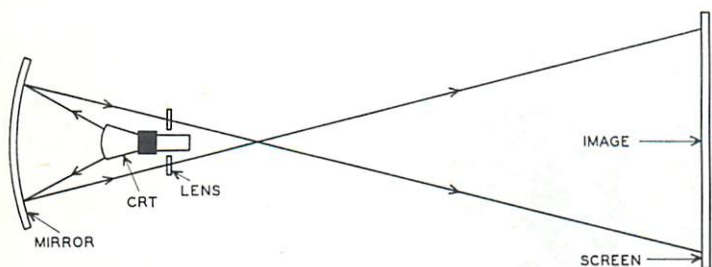


FIGURE 15

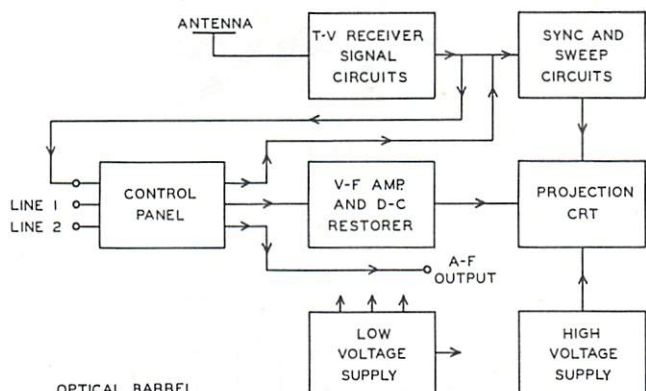


FIGURE 16

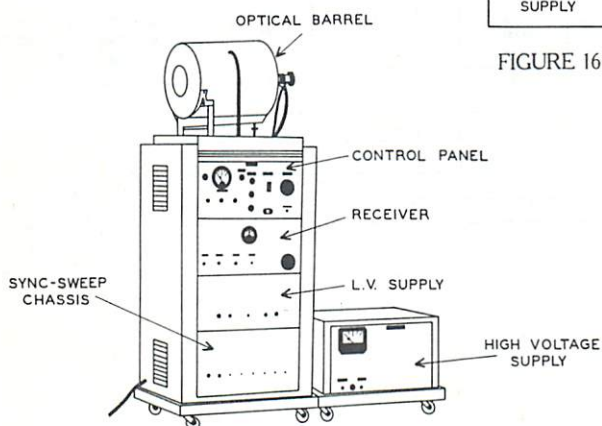


FIGURE 17

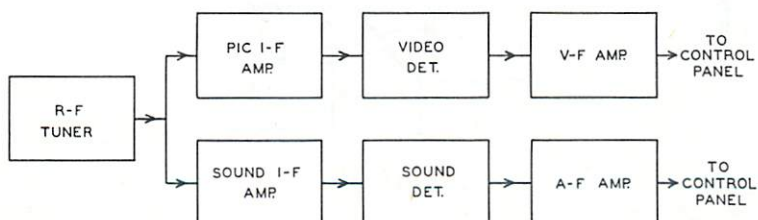


FIGURE 18

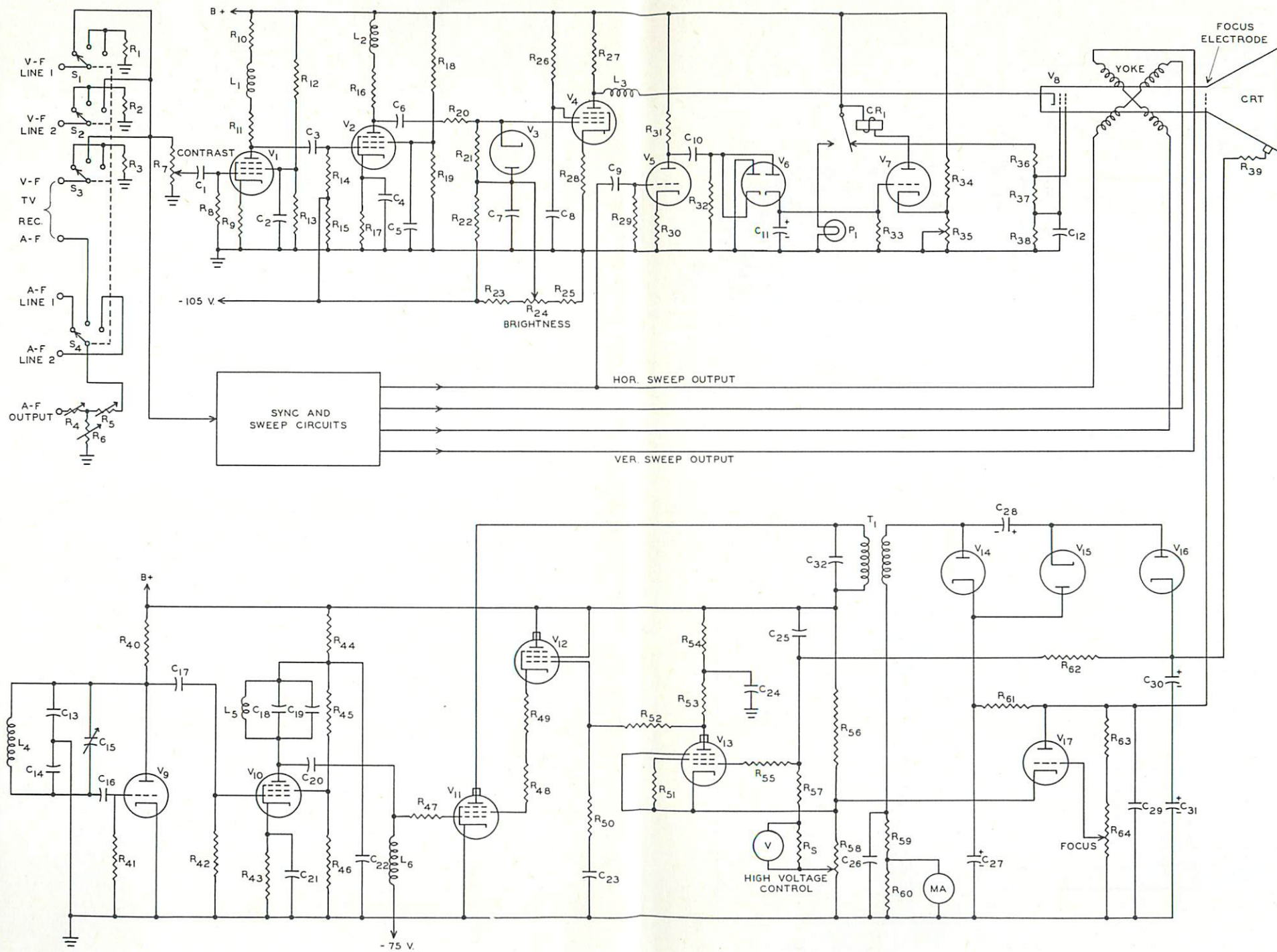


FIGURE 19

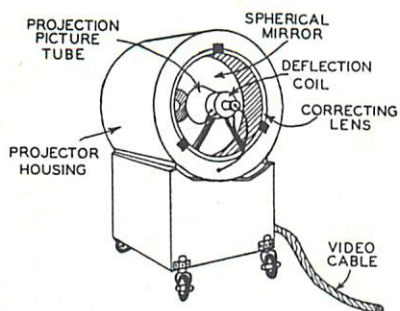


FIGURE 20

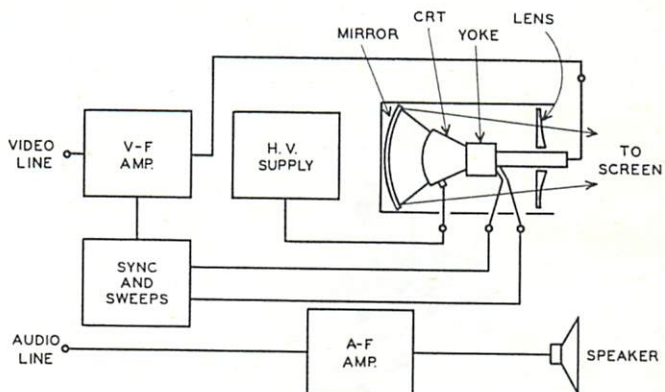


FIGURE 21

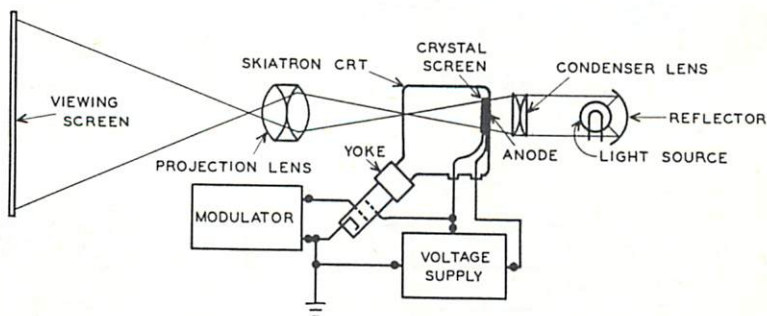


FIGURE 22

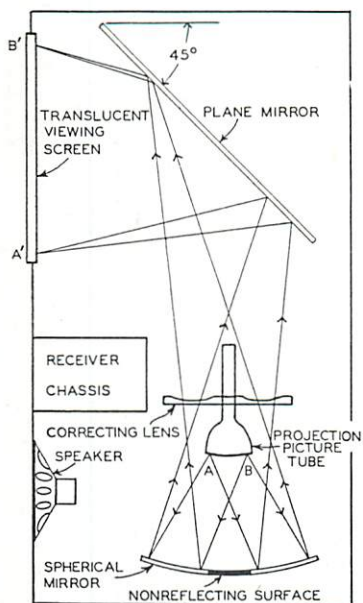


FIGURE 23

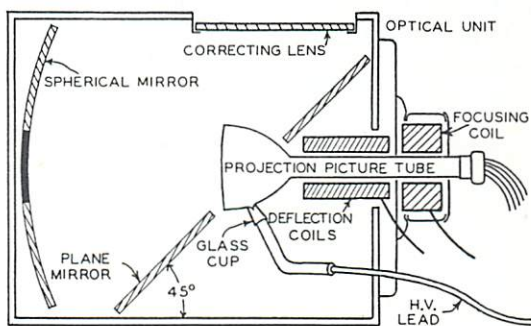


FIGURE 24

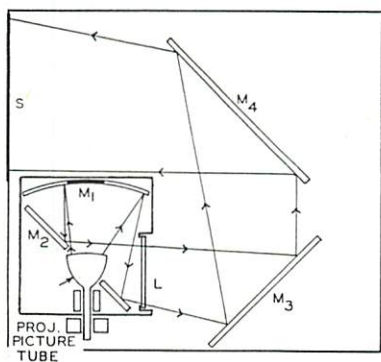


FIGURE 25

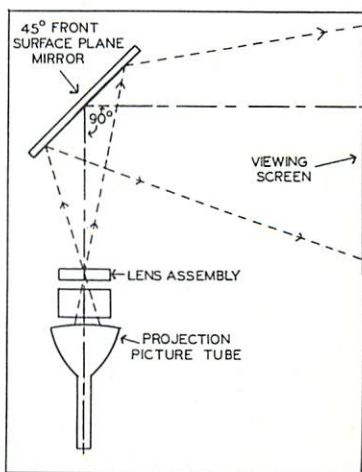


FIGURE 26

FROM OUR *Director's* NOTEBOOK

CAN YOU SING A SONG?

Can you sing a song to greet the sun,
Can you cheerily tackle the work to be done,
Can you vision it finished when only begun,
Can you sing a song?

Can you sing a song at the close of the day,
When weary and tired, the work's put away,
With the joy that it's won and the best of
the pay,
Can you sing a song?

Yours for success,

W. C. DeVry
DIRECTOR